The Use of Supply Chain Metrics in Lebanon: A Study of SCOR Applicability

By
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Masters of Business Administration in the major of Business

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This thesis came to an end with the kind support and participation of many individuals whose assistance was a milestone in the completion of this thesis.

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The Use of Supply Chain Metrics in Lebanon: A Study of SCOR Applicability

Zeina Kamel Huballah

ABSTRACT

One standard in measuring supply chain management success is that established by the SCOR model. The SCOR model was created by a management consulting firm of the Supply Chain Council which relies on specific performance measures that are related to the five-core process building blocks: Plan, Source, Make, Deliver, and Return with a sixth block of “Enable” added later. With its origins in Western/Developed Countries, there is some question about the applicability of the same metric system in Low- and Middle-Income Countries. This thesis relies on a survey methodology to explore the extent to which companies across multiple industries are measuring the SCOR Level 1 and Level 2 metrics in Lebanon and the MENA region. The results of the survey are analyzed via two machine learning techniques – an unsupervised clustering technique (kMeans) to identify companies with similar behavior relative to the SCOR metrics and a supervised learning technique (Classification Trees) to ascertain which company demographics (ie industry, age, size, age of employees, and SCOR familiarity) dictate cluster membership.

Keywords: Supply chain management, SCOR Model, SCOR performances, Developing Countries, MENA Region
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Chapter One

Introduction

Supply chain management (SCM) is the integration of key business processes that add value to the product or service, from the original suppliers through to the end-user who will consume the final product or service (Sillanpaa, 2012). SCM is an important part of all businesses as it governs the flow of raw material, information, and money, both upstream and downstream on three levels: strategic, tactical, and operational.

Measuring the success of supply chain decisions made at these three levels is an important aspect of SCM. One such measurement system is the Supply Chain Operations Reference (SCOR) model. The SCOR model is designed as a tool to describe, measure, and evaluate any supply chain configuration. Also, some companies use the SCOR model as a tool to evaluate and compare supply chains implemented either in global projects or within the firm. As mentioned by Huang, Sheoran, & Keskar (2005) “The SCOR model is intended to be an industrial standard that enables next-generation supply chain management”. To trace its history, SCOR was originally invented in 1996, by PRTM, a management consulting firm. SCOR is now inscribed by SCC (Supply chain council) that is a part of the American Production and Inventory Control Society framework (White, 2018).

SCOR allows practitioners to model and measure supply chain management by focusing on four main areas of management: performance, processes, practices, and people (Geogishe, Thoben, & Seifer, 2012). The first three areas (performance,
processes, and practices) are fundamentally related through their application to the main process building blocks standardized through SCOR. These processes can be fully fleshed out to the most detailed operational activity by identifying the processes, capabilities, business processes, and actions at Levels 1, 2, 3, and 4 of the framework, respectively.

The SCOR version 12.0 process model relies on six process building blocks of Planning, Sourcing, Making, Delivering, Returning, and Enabling (APICS, 2017) with the first process being planning which focusses on the process of balancing resources to accommodate the Sourcing, Making, Delivering, and Returning processes. The second process of sourcing is where functions related to procurement, receipt, and transfer of raw materials as well as works-in-progress are undertaken. Afterward, making, the core stage of the SCOR process, includes the activities that transform the raw materials into finished goods. Next, the delivery process involves the transportation and distribution of products to the company’s clients. The returning process, added in 2001, encompasses managing the reverse flow of goods and information from clients backward either to suppliers or the company. Finally, the enabling process is focused on all of the management tasks required to manage and report the information, relationships, resources, assets, business rules, compliance and contracts required to operate the supply chain.

Tied to each of these processes are different performance metrics. The performance metrics of SCOR version 12.0 are organized hierarchically with Level 1 metrics highlighting the strategic performance of the supply chain, Level 2 metrics pointing to the causes for Level 1 measures, and Level 3 metrics indicating the causes for the Level 2 values (APICS, 2017). These performance metrics can be categorized around the five categories of Reliability, Responsiveness, Agility, Cost, and Asset
Management. Moreover, Persson (2010) categorized the SCOR model KPIs into customer faced performance (reliability, responsiveness, and agility) and Internal facing attributes (cost and asset management). In this work, the most interesting section is the performance section of the SCOR model.

While the SCOR model is sufficiently robust to serve as an adequate evaluation tool for many different companies operating across multiple industries, it was ultimately designed in a North American context. In these contexts, the use of SCOR is likely to lead to faster model building and more effective utilization of the insights that they bring (Albores, Love, Weaver, Stone, & Benton, 2006). SCOR may not, however, be appropriate as an evaluation tool in all countries – in particular, in Low and Middle-Income Countries. According to the World Bank, Low and Middle-Income Countries (LMICs) are defined as those countries with a Gross National Income (GNI) per capita between $1,025 and $3,3995 using the World Bank Atlas Method. (Methodology, n.d.). Comparable to the World bank definition, there is the United Nations definition of LMICs as the countries that are vulnerable to economic and environmental shocks and consists of low levels of human assets (Secondary school enrolment, Under-Nourishments, Maternal Mortality, Adult literacy & Under Five mortality), Economic Vulnerability (Population, Remoteness, Export concentration, Victims of natural disasters, the share of agriculture and fishing in GDP, Share of population in coastal zones & Instability of agriculture) and Income per capita. (Desa, 2017).

Developed countries are categorized as a modern nation that is more industrialized, and generally have access to technology in advance of developing countries. In reality, an observer can see the spread of the supply chain SCOR model. There are a lot of companies adopting the SCOR model in developed countries like Walmart in
North America especially New York, Intel company in California, alfa Laval company in Sweden, Imanol Oil Company (IOC) in Iran\(^1\) (Seifbarghy, 2009). Furthermore, some of the developing countries adapted the SCOR model such as the leather industry in Ethiopia (Georgise, Thoben, & Seifert, 2015) and in the electrical industry in China\(^2\) (Han & Chu, 2009).

One reason that SCOR might not apply in LMICs is due to their predominant position as suppliers in global supply chains. For instance, Nigeria is rich in arable land and mineral sources, China is the number one producer of the gold and biggest producer and consumer of food and India’s major mineral resources include Coal, Natural gas and Diamonds (Sawe, 2019), but they lack supply chain management especially in using SCOR metrics. LMICs may also suffer from externalities that would hinder scores associated with reliability, responsiveness, and efficiency. To illustrate, research by Galal and Moneim (2016) discovered four characteristics of LMIC countries affecting the performance of supply chains: corruption, lack of infrastructure, pressing social problems in urban areas, and informality (Galal & Moneim, 2016).

Furthermore, the supply chain structure in LMICs is sometimes very different – even if meeting the important KPIs. For example, a supply chain in an LMIC may consist of only sources and customers. One study by the executive director Yvonne Agusten in the Philippines found that farmers extract the coconut milk from the coconuts and sell indirectly to the customers via online transactions. Thus, this supply chain consists of three stages, sourcing the coconuts, manufacturing it into coconut oil milk or coco chemicals, and then to customers (Agusten, 2014). Finally,

\(^1\) Iran is a semi-developed country: Is an industrialized country but not yet a developed one.

\(^2\) China is a semi-developed country
companies in LMICs may not be aware of the availability of tools for monitoring Supply Chain Performance. Georgise, Thoben, and Seifert (2013) wanted to measure the extent to which best practices have been implemented in companies within LMICs. To that end, they studied the implementation of supply chain management in Ethiopia, based on certain practices like Total Quality Management, Benchmarking, Available to Promise (ATP), Carrier agreement, outsourcing and ten other practices using a scale ranging from 1 to 4 where 1 = never implemented, 2 = poorly implemented, 3 = well implemented, and 4 = extensively implemented and according to conduct questionnaires and semi-structured interviews to collect data from Ethiopian countries to ensure a comprehensive representation. In so doing, they discovered that total quality management is found to be the leading best practice, with a mean score of 2.48.

In Lebanon, many of the Lebanese agriculture production systems are facing huge problems such as feed shortage, labor expenses, low productivity, and poor management of the organic matter (El Balaa & Marie). As Lebanon is one of the developing countries, the dynamicity, and uncertainty of business environments and lack of institutions prevent supply chains from learning and innovating which makes it difficult to achieve competitive advantage in the market (Galal & Moneim, 2016). Consequently, working on applying the SCOR model may help businesses organize their supply chain processes which increase their sales. Thus, it is important to build a SCOR model that is specific to Lebanon.

This thesis beings, in the Introduction with an explanation of the SCOR model and then proceeds to the main goal of examining the prevalence of measuring SCOR metrics across industries in Lebanon even if SCOR is not directly applied in its full intended form. The subsequent section, the Literature Review, shows that there are
some important gaps regarding supply chain measurement and specifically tools to
assess industry use of supply chain measurement systems. The Methodology section
then explains the method that was used to collect the data and how the survey was
designed. Chapter 4 is the heart of this work and describes the analytical tools that
were used to analyze the collected data as well as the results coming from the
analysis performed. Last but not least, the Conclusion and Discussion section
summarizes the whole paper and highlights the objectives of the thesis that have been
achieved while recommending actions for managers and researchers through a
statement of future research relative to this study.
Chapter Two

Literature Review

It's very common for the companies to measure Supply Chain Performances to know where a company stands in the market. And the metrics that are used in order to measure supply chain management differs from one company to another. To start with some companies measure supply chain management according to the delivery rates, such as the Fill Rate metric that measures the percentage of orders that are delivered on the day that is requested by the customer, Confirmed Fill Rate that measures the percentage of orders that are delivered within the negotiated days between the supplier and the customer and no longer than the agreed day and Response delay which measures the difference Fill Rate and the Confirmed Fill Rate. (Kleijnen & Smits, 2003). The researcher Dr. Sillanpaa mentioned in "Empirical Study of Measuring Supply Chain Performance" (2012) the importance of measuring the Profitability metric of the companies, as Return on Asset Ratio measures the supply chain management from the cost efficiency perspective because it measures the ability of the company to generate profit while managing its assets. Another supply chain management metric is the Balanced Scorecard (BSC), this metric is a strategic management system that measures every detail of the company's financial and non-financial performances to monitor the company's growth internally and externally (Chang, Hung, Wong, & Lee, 2012).

The SCOR model is a management model that consists of consecutive business activities and tests performance at three levels to address, improve and communicate...
supply chain decisions within a company in a particular industry so the company can satisfy the customers’ demand. First, Level 1 metrics are the calculations that are used by the company to check where it stands in achieving its goal within the competitive industry. Second, Level 2 performance metrics serve as a monitor to Level 1 metrics, this means that while calculating Level 2 metrics, the company could detect and explain the performance gaps in Level 1. Last, Level 3 metrics serve as a diagnostic for Level-2 metrics, this thesis sheds a light on Level 1 and Level 2 of metrics of the SCOR model. This choice was made because Level 1 defines metrics associated with processes and is made up of the lower-order metrics captured at Level 2. Thus, the data solicited from the companies will indicate whether the companies measure the equation alone – Level 1, the metrics alone – Level 2, or both (APICS, 2017). This research does go to one more level of depth in capturing the frequency of measure associated with three cost performance metrics of Level 3: Direct Cost, Direct Material Cost and Indirect Cost Related To Material as these performance metrics are important for the companies in order to make the right decision (Cooper & Kaplan, 1988).

The use of clustering to identify companies with similar management strategies is not new in the literature (Feser, 1998) and has found some traction in segmenting service companies in general (Wang, 2010) and in specific fields such as retail financial services (Speed & Smith, 1992).

To the best of our knowledge there are only a few studies using cluster analysis relative to supply chain behaviors. In 2010, Kannan & Tan sought to study the relationship between supply chain performance and patterns of supply chain integration with partners. Through their work, they identified two clusters indicating differential supply chain success relative to the pattern of integration; however,
unlike this work their measures of supply chain performance were not tied to the SCOR model (Kannan & Tan, 2010). Similarly, another study using clustering was undertaken by Bosona in “Cluster Building and Logistics Network Integration of Local Food Supply Chain” (2010) and aimed to investigate local food supply chain characteristics in order to improve logistics efficiency and increase profitability. The integrated logistics network was made by creating two clusters of producers to determine their collection centers (Bosona, 2011). In contrast to these studies, these thesis clusters companies within Lebanon and the MENA based on the frequency with which they measure specific metrics. With these clusters, a classification strategy serves to identify which industries are utilizing the SCOR metrics and in what way.
Chapter Three

Methodology

Before engaging in a survey methodology, we did a scan of thirty articles on the current state of supply chain measurement. It was through this scan that the SCOR model was selected as the prominent method of supply chain management both for its thoroughness and for its use in industry and academic research. All in all, the methodology applied in this study is divided into five steps. The first step involves designing the survey. The survey includes three parts. The first part of the survey includes seven demographic questions about the company in general. The second portion of the survey solicits information on how frequently the company collects the ten SCOR level one measure as per the SCOR Version 12.0 model. The third portion of the survey examines the frequency with which the company collects the 35 SCOR level two and three performance metrics. The possible answers in both sections two and three of the survey are never, once per year, twice per year, once per quarter, and once per month. The second step in this section is to convert this survey to an online format for easy distribution and secure, environmentally friendly, collection of results. Subsequently, we undertook the third step of gaining approval from IRB. The fourth step is to distribute the survey to managers of companies in Lebanon. The distribution process of the survey starts with sharing the link of the online google form through the LinkedIn application, as my connections on Linkedin consist of many managers of small-medium Lebanese companies. Then, I posted it on Facebook as I can reach managers and business owners more easily than any social media platform. After that, I took a sample of Lebanese Businessmen from websites.
such as, “lebanonbusinessdirectory” in order to email the survey to them. Also, some managers could not be reached on social media platforms. So, the link was filled directly from the phone by visiting the manager's workplace. The fifth step is to analyze the data arising from the survey. In the analysis of the survey results, we will identify which performance metrics are collected most frequently in Lebanon. We will also identify synergies between measures – are there measures/groups of measures that are frequently collected together? Do these “measure clusters” point to a particular SCOR area that is more emphasized in Lebanon than others are?

In order to determine how companies, measure the SCOR Level 1 and Level 2 metrics in Lebanon, the responses provided by each company representative were grouped via cluster analysis. Cluster analysis is a technique aimed at finding patterns in data in the form of clusters. A cluster is a set of observations that are more similar to each other than they are to individuals in other clusters. “The purpose of cluster analysis is to identify patterns in your data and create groups according to those patterns” (Fonseca, 2019). This research paper aims to divide the respondents into groups based on how frequently the companies measure Level 1 and Level 2 SCOR performance metrics.

Chapter Four

Analysis and Results

In this chapter, we describe the analysis performed on the data and summarize the result of this analysis.

4.1 Analysis

Data analysis proceeded as follows. The first step was cleaning the survey data. The responses of respondents who checked a specific number of performance metrics while leaving the majority empty were removed. It was not possible to impute the missing data with the most frequent answer in the cases that the majority of performance metrics were left unchecked. Furthermore, respondents who did not answer to which industry their company belongs were removed as this question is one of the most important variables that the research paper relies on. On the other hand, some respondents left one or two metrics unchecked, so the most frequent answer in each level was taken as an answer in order not to lose such important data. After cleaning the data, we were left with a dataset of 63 useable responses. All subsequent analysis was performed in R (R Core Team, 2019) and figures were produced using the packages cluster (Marvghler,Rousseeuw, Struyf,Hubert and Hornik, 2019), ggplot2 (Wickham, 2016) and evtree (Grubinger,Zeileis and Periffer, 2014).

The Respondent’s Demographics in Table 1 shows the answers of the respondents concerning the 7 demographic questions that were asked in the survey. These
respondents were from Lebanon (51) and other MENA region countries, such as Egypt (6), Jordan (3), Kuwait (2), and United Arab of Emirates (1).

Table 1: Respondent’s Demographics

<table>
<thead>
<tr>
<th>Variables</th>
<th>Option (Responses)</th>
<th>Frequency (Responses)</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Have you heard of the Supply Chain Operations Reference (SCOR) model?</td>
<td>1. Yes</td>
<td>26</td>
<td>41.27%</td>
</tr>
<tr>
<td></td>
<td>2. No</td>
<td>37</td>
<td>58.73%</td>
</tr>
<tr>
<td>Does your company use the Supply Chain Operations Reference (SCOR) model?</td>
<td>1. Yes</td>
<td>28</td>
<td>44.44%</td>
</tr>
<tr>
<td></td>
<td>2. No</td>
<td>35</td>
<td>55.56%</td>
</tr>
<tr>
<td>Does your company provide training in the Supply Chain Operations Reference (SCOR) model?</td>
<td>1. Yes</td>
<td>22</td>
<td>34.92%</td>
</tr>
<tr>
<td></td>
<td>2. No</td>
<td>41</td>
<td>65.08%</td>
</tr>
<tr>
<td>What is the average age of the employees</td>
<td>1. 20-30 Years</td>
<td>19</td>
<td>30.16%</td>
</tr>
<tr>
<td></td>
<td>2. 30-40 Years</td>
<td>31</td>
<td>49.21%</td>
</tr>
<tr>
<td></td>
<td>3. 40-50 Years</td>
<td>7</td>
<td>11.11%</td>
</tr>
<tr>
<td></td>
<td>4. 50-60 Years</td>
<td>2</td>
<td>3.17%</td>
</tr>
<tr>
<td></td>
<td>5. 60+ Years</td>
<td>4</td>
<td>6.35%</td>
</tr>
<tr>
<td>What is the age of the company/how long has your company been in operation?</td>
<td>1. 0-5 Years</td>
<td>7</td>
<td>11.11%</td>
</tr>
<tr>
<td></td>
<td>2. 5-10 Years</td>
<td>7</td>
<td>11.11%</td>
</tr>
<tr>
<td></td>
<td>3. 10-15 Years</td>
<td>11</td>
<td>17.46%</td>
</tr>
<tr>
<td></td>
<td>4. 15-20 Years</td>
<td>7</td>
<td>11.11%</td>
</tr>
<tr>
<td></td>
<td>5. 20+ Years</td>
<td>31</td>
<td>49.21%</td>
</tr>
<tr>
<td>What is the company’s industry?</td>
<td>1. Agriculture</td>
<td>1</td>
<td>1.59%</td>
</tr>
<tr>
<td></td>
<td>2. Construction</td>
<td>6</td>
<td>9.52%</td>
</tr>
<tr>
<td></td>
<td>3. Education</td>
<td>13</td>
<td>20.63%</td>
</tr>
<tr>
<td></td>
<td>4. Food Industry</td>
<td>2</td>
<td>3.17%</td>
</tr>
<tr>
<td>5. Financial Services</td>
<td>14</td>
<td>22.22%</td>
<td></td>
</tr>
<tr>
<td>-----------------------</td>
<td>----</td>
<td>--------</td>
<td></td>
</tr>
<tr>
<td>6. Sales</td>
<td>17</td>
<td>26.98%</td>
<td></td>
</tr>
<tr>
<td>7. Sports</td>
<td>1</td>
<td>1.59%</td>
<td></td>
</tr>
<tr>
<td>8. Technology</td>
<td>9</td>
<td>14.29%</td>
<td></td>
</tr>
</tbody>
</table>

What is the size of your company? (Employees)

<table>
<thead>
<tr>
<th>1. 0-100 Employees</th>
<th>21</th>
<th>33.33%</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. 100-200 Employees</td>
<td>8</td>
<td>12.70%</td>
</tr>
<tr>
<td>3. 200-300 Employees</td>
<td>7</td>
<td>11.11%</td>
</tr>
<tr>
<td>4. 300-400 Employees</td>
<td>4</td>
<td>6.35%</td>
</tr>
<tr>
<td>5. 400+ Employees</td>
<td>23</td>
<td>36.51%</td>
</tr>
</tbody>
</table>

The second step is to standardize the data. In order to perform clustering, the data must be all numeric and scaled to be comparable. To scale the data, a subtraction of the mean of the variable was done from each entry and then dividing by the standard deviation of that variable.

The third step is to calculate the clustering distance, in other words, the distance between each data point and the centroid of a specific cluster to define the similarity and dissimilarity of two elements with (x, y) dimensions. “The classification of observations into groups requires some methods for computing the distance or the (dis)similarity between each pair of observations” (Boehmke, 2018). In this study, we used Euclidean distance as our measure of distance. On the basis of the distance plot across all respondents shown in we chose to proceed with a kMeans cluster strategy with 5 centers.

“K-means clustering is the most commonly used unsupervised machine learning algorithm for partitioning a given data set into a set of k groups” (Boehmke, 2018). K stands for the number of groups, and each group consists of the respondents that have similar values for a given variable. Each group has its own mean value and variance.
For this research study, it was found $k=5$ modeled the data best. When $k=4$ was tested, the clusters were too large and for $k=6$, the $k$ were too similar to each other. The results of the K-means cluster analysis is the topic of the next chapter.

After identifying companies whose SCOR metric measuring frequency is similar, we used another machine learning algorithm – classification trees – to identify what company demographics may influence cluster membership. In this way, we can obtain a full view of what types of companies measure which levels of SCOR metrics more or less frequently. This in turn will allow for a series of recommendations on how Supply Chain Strategy can be measured in LMICs in general and how the SCOR system can be introduced in specific.

### 4.2 Results

Table Table 2: Descriptive Statistics defines each tested SCOR metric performance and states the mean and median as measures of central tendency and the standard deviation as a measure of dispersion based on the results of the questionnaire.

<table>
<thead>
<tr>
<th>Level 1</th>
<th>Performances</th>
<th>Definition</th>
<th>Mean</th>
<th>Median</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>RL.1</td>
<td>Reliability Performance = (Total perfect Order/Total Number of Orders) * 100</td>
<td>3.44</td>
<td>3</td>
<td>1.42</td>
<td></td>
</tr>
<tr>
<td>RS.1</td>
<td>Order Fulfillment Cycle Time</td>
<td>3.54</td>
<td>4</td>
<td>1.38</td>
<td></td>
</tr>
<tr>
<td>AG.1.1</td>
<td>Upside Supply Chain Adaptability</td>
<td>3.29</td>
<td>3</td>
<td>1.42</td>
<td></td>
</tr>
<tr>
<td>AG.1.2</td>
<td>Downside Supply Chain Adaptability</td>
<td>3.30</td>
<td>3</td>
<td>1.42</td>
<td></td>
</tr>
<tr>
<td>AG.1.3</td>
<td>Overall Value-at-Risk (VaR)</td>
<td>3.40</td>
<td>3</td>
<td>1.39</td>
<td></td>
</tr>
<tr>
<td>Level 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---------</td>
<td>------------------</td>
<td>---</td>
<td>---</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CO.1.1</td>
<td>Total Supply Chain Management Cost</td>
<td>3.32</td>
<td>3</td>
<td>1.41</td>
<td></td>
</tr>
<tr>
<td>CO.1.2</td>
<td>Cost of Goods Sold</td>
<td>3.65</td>
<td>4</td>
<td>1.39</td>
<td></td>
</tr>
<tr>
<td>AM.1.1</td>
<td>Cash to Cash Cycle Time</td>
<td>3.62</td>
<td>4</td>
<td>1.37</td>
<td></td>
</tr>
<tr>
<td>AM.1.2</td>
<td>Return on Fixed Assets</td>
<td>3.37</td>
<td>3</td>
<td>1.44</td>
<td></td>
</tr>
<tr>
<td>AM.1.3</td>
<td>Return on Working Capital</td>
<td>3.41</td>
<td>3</td>
<td>1.41</td>
<td></td>
</tr>
<tr>
<td>RL.2.1</td>
<td>Total Number of Perfect Orders</td>
<td>3.56</td>
<td>4</td>
<td>1.35</td>
<td></td>
</tr>
<tr>
<td>RL.2.2</td>
<td>Total Number of Orders</td>
<td>3.67</td>
<td>4</td>
<td>1.33</td>
<td></td>
</tr>
<tr>
<td>RS.2.1</td>
<td>Source Cycle Time</td>
<td>3.41</td>
<td>3</td>
<td>1.34</td>
<td></td>
</tr>
<tr>
<td>RS.2.2</td>
<td>Make Cycle Time</td>
<td>3.46</td>
<td>4</td>
<td>1.33</td>
<td></td>
</tr>
<tr>
<td>RS.2.3</td>
<td>Deliver Cycle Time</td>
<td>3.60</td>
<td>4</td>
<td>1.45</td>
<td></td>
</tr>
<tr>
<td>RS.2.4</td>
<td>Deliver Retail Cycle Time</td>
<td>3.57</td>
<td>4</td>
<td>1.41</td>
<td></td>
</tr>
<tr>
<td>RS.2.5</td>
<td>Return Cycle Time</td>
<td>3.44</td>
<td>4</td>
<td>1.54</td>
<td></td>
</tr>
<tr>
<td>AG.2.1</td>
<td>Maximum sustainable percentage increase in raw material quantities that can be acquired/received in 30 days]</td>
<td>3.10</td>
<td>3</td>
<td>1.59</td>
<td></td>
</tr>
<tr>
<td>AG.2.2</td>
<td>Maximum sustainable percentage increase in production that can be achieved in 30</td>
<td>3.10</td>
<td>3</td>
<td>1.59</td>
<td></td>
</tr>
<tr>
<td>AG.2.3</td>
<td>Maximum sustainable percentage increase in quantities delivered that can be achieved in 30 days]</td>
<td>3.13</td>
<td>3</td>
<td>1.52</td>
<td></td>
</tr>
<tr>
<td>AG.2.4</td>
<td>Maximum sustainable</td>
<td>3.10</td>
<td>3</td>
<td>1.55</td>
<td></td>
</tr>
<tr>
<td>AG.2.5</td>
<td>Maximum sustainable percentage increase in returns of raw materials to suppliers that can be achieved in 30 days</td>
<td>3.27</td>
<td>3</td>
<td>1.50</td>
<td></td>
</tr>
<tr>
<td>AG.2.6</td>
<td>Raw material quantity reduction sustainable at 30 days prior to delivery with no inventory or cost penalties</td>
<td>3.08</td>
<td>3</td>
<td>1.58</td>
<td></td>
</tr>
<tr>
<td>AG.2.7</td>
<td>Production reduction sustainable at 30 days prior to delivery with no inventory or cost penalties</td>
<td>3.00</td>
<td>3</td>
<td>1.59</td>
<td></td>
</tr>
<tr>
<td>AG.2.8</td>
<td>Reduction in delivered quantities sustainable at 30 days prior to delivery with no inventory or cost penalties</td>
<td>2.89</td>
<td>3</td>
<td>1.54</td>
<td></td>
</tr>
<tr>
<td>AG.2.9</td>
<td>Probability of Risk Event</td>
<td>2.95</td>
<td>3</td>
<td>1.41</td>
<td></td>
</tr>
<tr>
<td>AG.2.11</td>
<td>Cost of Risk Event</td>
<td>3.06</td>
<td>3</td>
<td>1.32</td>
<td></td>
</tr>
<tr>
<td>AG.2.12</td>
<td>Time to Recover</td>
<td>3.17</td>
<td>3</td>
<td>1.43</td>
<td></td>
</tr>
<tr>
<td>CO.2.1</td>
<td>Cost to Plan</td>
<td>3.37</td>
<td>4</td>
<td>1.35</td>
<td></td>
</tr>
<tr>
<td>CO.2.2</td>
<td>Cost to Source</td>
<td>3.21</td>
<td>3</td>
<td>1.30</td>
<td></td>
</tr>
<tr>
<td>CO.2.3</td>
<td>Cost to Make</td>
<td>3.37</td>
<td>4</td>
<td>1.35</td>
<td></td>
</tr>
<tr>
<td>CO.2.4</td>
<td>Cost to Deliver</td>
<td>3.56</td>
<td>4</td>
<td>1.32</td>
<td></td>
</tr>
<tr>
<td>CO.2.5</td>
<td>Cost to Deliver</td>
<td>3.56</td>
<td>4</td>
<td>1.32</td>
<td></td>
</tr>
<tr>
<td>CO.2.6</td>
<td>Mitigation Cost</td>
<td>3.27</td>
<td>3</td>
<td>1.53</td>
<td></td>
</tr>
<tr>
<td>CO.3.1</td>
<td>Direct Labor Cost</td>
<td>3.60</td>
<td>4</td>
<td>1.34</td>
<td></td>
</tr>
<tr>
<td>CO.3.2</td>
<td>Direct Material Cost</td>
<td>3.56</td>
<td>4</td>
<td>1.32</td>
<td></td>
</tr>
<tr>
<td>CO.3.3</td>
<td>Indirect Cost Related to Production</td>
<td>3.22</td>
<td>3</td>
<td>1.41</td>
<td></td>
</tr>
<tr>
<td>AM.2.1</td>
<td>Inventory Days of Supply</td>
<td>3.48</td>
<td>4</td>
<td>1.31</td>
<td></td>
</tr>
<tr>
<td>AM.2.2</td>
<td>Days Sales Outstanding</td>
<td>3.51</td>
<td>4</td>
<td>1.35</td>
<td></td>
</tr>
<tr>
<td>---------</td>
<td>------------------------</td>
<td>------</td>
<td>----</td>
<td>------</td>
<td></td>
</tr>
<tr>
<td>AM.2.3</td>
<td>Days Payable Outstanding</td>
<td>3.56</td>
<td>4</td>
<td>1.32</td>
<td></td>
</tr>
<tr>
<td>AM.2.4</td>
<td>Supply Chain Revenue</td>
<td>3.56</td>
<td>4</td>
<td>1.34</td>
<td></td>
</tr>
<tr>
<td>AM.2.5</td>
<td>Supply Chain Fixed Assets</td>
<td>3.44</td>
<td>4</td>
<td>1.35</td>
<td></td>
</tr>
<tr>
<td>AM.2.6</td>
<td>Accounts Payable</td>
<td>3.67</td>
<td>4</td>
<td>1.33</td>
<td></td>
</tr>
<tr>
<td>AM.2.7</td>
<td>Accounts Receivable</td>
<td>3.65</td>
<td>4</td>
<td>1.39</td>
<td></td>
</tr>
<tr>
<td>AM.2.8</td>
<td>Inventory</td>
<td>3.63</td>
<td>4</td>
<td>1.43</td>
<td></td>
</tr>
</tbody>
</table>

In Table 2 the mean values reflect the expected frequency with which the companies measure the specified performance metric. In this regard, we note that within the Level 1 metrics, two metrics which are upside supply chain adaptability and downside Supply chain adaptability are the least frequently measured, while the cost of goods sold and cash to cash cycles are the most frequently measured items. For the Level 2 metrics, the majority of the agility Level 2 performance metrics are measured less frequently than all the other. The median reflects the frequency at or beyond which 50% of the respondents measure the specified metrics. Finally, the standard deviation measures the average distance between the tested performance and the mean. The standard deviation reflects the variability in the sample surrounding the frequency with which the particular metric is measured – a smaller standard deviation implies more consistency among the respondents in terms of their frequency by which they measure the given metric.

**4.2.1 All Metric Data Cluster Results:**

In order to apply the kMeans cluster technique, the number of clusters must be provided a priori. One way to determine the number of means to use is based on the
distance as showed in Figure 1.

Figure 2 illustrates the distance between the answers of the respondents. As the research paper aims to divide the respondents into clusters. The graph consists of two dimensions, and each dimension represents a listing of the respondents described by their industrial sector and a unique ID number. The darker the red color, the greater the distance between the companies, while the darker the blue color, the more similar the companies are. First, it can be noticed that the largest blue square in the lower left of the heat map is made up mostly of companies in financial services. This shows that companies with in the same sector – namely financial services – tend to measure
SCOR metrics with the same frequency. The same goes for the second blue square along the diagonal that matches sales companies, the third blue square on the diagonal that matches education companies, technology, and education companies in 4th square and 5th square that is on the top of the diagonal that matches education, technology, and other sectors together. Thus, with five fairly clear “boxes” along the diagonal in the distance-based heatmap, a decision to model the full data set using 5 cluster means was made.

By applying the k-Means clustering algorithm over the full dataset of 63 respondents relative to their responses on the frequency with which they measure the SCOR metrics, but excluding the demographic indicators, a set of 5 clusters was obtained. These clusters are depicted in Figure 1: All data model cluster plot, which shows that all observations form five homogenous and distinct clusters concerning Level 1 performance metrics on dimension 1 and Level 2 and 3 performances on dimension 2. The observations that are in the same clusters are similar to each other concerning how frequently each company measures the SCOR Level 1 metrics.
**Table 3: All Model Data**

<table>
<thead>
<tr>
<th>Industry</th>
<th>Cluster 1</th>
<th>Cluster 2</th>
<th>Cluster 3</th>
<th>Cluster 4</th>
<th>Cluster 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Construction</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Education</td>
<td>0</td>
<td>4</td>
<td>2</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Financial Services</td>
<td>10</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Food Industry</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Sales</td>
<td>2</td>
<td>5</td>
<td>5</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Sports; Football Field</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Technology</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

It can be noted from Table 3 that Cluster 1 contains the most financial services companies among all other clusters. The centroid of Cluster 1 is the farthest left centroid in the diagram which means that the financial services industry measures the SCOR model performance metrics more frequently than the other industries.

*Figure 2: Cluster Map of Companies Relative to All SCOR Metrics Frequency of Measure*
In order to gain more insight into what differentiates the clusters from each other, a heat-map that contains all measured SCOR metrics relative to the centers of each cluster is presented in Figure 3. Cluster 1 appears to represent the financial services industry and the dark red color of the Cluster 1 column indicates that companies in this cluster, dominated by financial services companies, measure the agility, asset management, and cost performance metrics on all levels more frequently than the other industries. The majority of companies in Cluster 2 are from sales and construction industries; these companies measure the Level 1 and Level 2 asset management performances more than other performance metrics with several Level 2 cost performance metrics. Next, Cluster 3 is the moderate cluster which is predominately related to the sales industry which measures all the performance metrics but they measure the Level 3 agility performance metrics at a frequency greater than in other industries. Cluster 4 is dominated by sales and technology. In this cluster, the companies measure the Level 2 metrics of responsiveness and asset management the most, on the other hand barely do these companies measure the Level 2 metrics of agility performance. Meanwhile, Cluster 5 is dominated by the education industry which measures asset management and costs less frequently than the other metrics; but in general, do not measure any metrics particularly frequently.
Figure 3: Heat Map of SCOR Metric Measuring Frequency by Cluster
Figure 4 shows how the company demographic variables serve to predict cluster membership. This tree was derived from the data using the evtree package in R (Grubinger, Zeileis and Periffer, 2014). The tree diagram shows that the most important company feature is to derive cluster membership is the industry. Specifically, the root node yields two branches, the first branch is made up of the agriculture, financial services, construction, and education industries and this branch shows that these companies are most likely to fall into Cluster 1 which is characterized by the extreme frequency with which they measure all the SCOR metrics. The second branch contains sales, technology, and sports industries. It can be noticed from the diagrams that the number of years that a company has been operating in the market plays a big role in measuring the performance metrics when it comes to the following industries: Financial services, construction, food, sales, and technological industries. As the companies that have been operating up to 15 years
within the construction and financial services industries measure the asset management and cost performance metrics the most. And the companies that are related to sales, technology, and food industries measure agility the most. Moreover, the companies that are the oldest in their field with up to 20 years in the market tend to belong to Cluster 2 and measure Level 1 and Level 2 asset management performances and some Level 2 cost performance metrics. From these results, we see that overall the frequency with which each metric group and level is measured varies by the cluster. To explore the relationship between the companies and each particular metric type, a further set of k-Means cluster analyses were run, one for each metric type.

4.2.2 Reliability Model Performance:

Reliability performance in the SCOR model represents the metrics that are related to the outcome of the process, reliability attributes consist of every task that is related to providing the products in the right quantity, right quality, and at the right time (APICS, 2017).

Table 4: Reliability Model Data

<table>
<thead>
<tr>
<th>Industry</th>
<th>Cluster 1</th>
<th>Cluster 2</th>
<th>Cluster 3</th>
<th>Cluster 4</th>
<th>Cluster 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Construction</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Education</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>Financial Services</td>
<td>0</td>
<td>2</td>
<td>11</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Food Industry</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Sales</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Sports; Football Field</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Technology</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>
The clusters that are represented in Figure 5, show that all observations form five homogenous and distinct clusters. As it can be noticed from Table 4 that most of the financial services companies are allocated in Cluster 3, and this green cluster is located in the middle of the right edge of figure 4, as well as the centroid is on the vertex of greenish Cluster 3 triangles which means that financial services industry measures the reliability performances more frequently than the other industries.
In order to gain more insight into what differentiates the clusters from each other, a heat-map that contains the reliability metric performances relative to the centers of each cluster is presented in Figure 6: Reliability Model Heat Map. Furthermore, Cluster 1 appears to represents the sales industry and the blue color in the first cluster shows that the sales industry does not measure level 1 of reliability performance but measure the level 2 performance that is the Total Number of Orders the most among all other clusters. The majority of companies in Cluster 2 are from the education industry and these companies measure the level 1 a bit more frequently than level 2 performances. Next, Cluster 3, the hyper cluster that is made up of the financial services industry and these companies measure all level 1 and level 2 performances more frequently than the other companies. Next, the majority of companies belong to the education and sales industries which they measure level 1 and level 2 performance a way below average. Moreover, Cluster 5 is dominated by the sales companies that measure level 1 and level 2 performance on average.
In closing, Figure 7 shows what the cluster diagram wasn’t able to show based on the seven demographic questions in the survey. This tree was derived from the data on using the evtree package in R (Grubinger, Zeileis & Pfeiffer, 2014). The tree diagram shows that the most important partition to derive cluster membership is the industry. Specifically, the root node yields two branches, the first branch is made up of the agriculture, construction, and education industries and this branch shows that these companies are most likely to fall into Cluster 3 which measures all the level 1 and level 2 reliability performances. The second branch contains of sales, technology and sports industries. It can be noticed from the diagrams that the number of years that a company has been operating in the market plays a big role in measuring the reliability performances of the second branch industries. Well, the companies that are the oldest in this field measures all the reliability performances on average. While, the majority of the companies that are related to sales, technology, and food industries that have been operating for 5 years tends to belong to Cluster 4 that measures the reliability performances less often than the other industries.

Figure 7: Reliability Model Tree Diagram
4.2.3 Responsive Model Performance:

Responsiveness performance measures the velocity at which the company provides the products to the consumers, such as measuring Order Fulfillment Cycle Time, Source and Make Cycle Time, and other metrics related to Time (APICS, 2017).

Table 5: Responsiveness Model Data

<table>
<thead>
<tr>
<th>Industry</th>
<th>Cluster 1</th>
<th>Cluster 2</th>
<th>Cluster 3</th>
<th>Cluster 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Construction</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Education</td>
<td>5</td>
<td>0</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Financial Services</td>
<td>2</td>
<td>11</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Food Industry</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Sales</td>
<td>2</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Sports; Football Field</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

Figure 8: Responsiveness Model Cluster Plot
Applying the K-cluster algorithm on the responses here with k=5 on responsiveness metric responses showed that there is an additional cluster that doesn’t give us any new additional information, so a decision was made to associate these companies with 4 clusters. With this clustering, most of the education companies lie in Cluster 1, the majority of financial services are in Cluster 2, and Cluster 3 and 4 consist of a combination of both education and sales industry. It can be noticed in Figure 7 that Cluster 2 is located in the far right of the diagram, Cluster 1 is in the far left of the diagram and Clusters 3 and 5 are in the middle of the diagram.

![Figure 9: Responsiveness Model Heat Map](image)
To elaborate, Figure 9 shows that Cluster 1 is made up of the education sector, these companies measure the responsiveness metrics less frequently among all other industries and doesn’t measure the “Make cycle time” metric at all. While Cluster 2 that contains the financial services countries measure level 1 and level 2 of responsiveness performance metrics the most frequently among all the other clusters. Although Cluster 3 and 4 is a combination of sales and education industry, what differentiates Cluster 3 more is that it contains a couple of construction companies. The companies in Cluster 3 measure the three Level 2 performance metrics which are: Deliver cycle time, deliver retail cycle time, and return cycle time more frequently than the other metrics. Rarely do the companies that are in Cluster 4 measure the responsiveness performances.

![Figure 10: Responsiveness Model Tree Diagram](image)

Figure 10: Responsiveness Model Tree Diagram
In closing, Figure 10 shows what the cluster diagram wasn't able to show based on the seven demographic questions in the survey. This tree was derived from the data using the evtree package in R (Grubinger et al., 2014). The Responsiveness Model Tree Diagram shows that the most important partition to derive cluster membership is the industry. Specifically, the root node yields two branches, the first branch is made up of the financial services, agriculture, and construction industries, and this branch yield to two sub-branches. The first sub-branch contains the Agriculture and financial services companies, if these companies heard about the SCOR model before they belong to Cluster 1, while those who didn’t hear about it belong to the 4th Cluster. The second sub-branch is made up of food and sports industries, and the majority of these companies are placed in Cluster 2. To go back to the second branch, the companies that are related to education and sports industries with an average age of employees between 30-40 and 50-60 years old belong to Cluster 4 and the companies with an average age of employees between 20-30 and 40-50 lay down in Cluster 1.

4.2.4 Agility Model Performance:

Agility Performance measures the ability of the company to respond and adapt to market changes, in other words it consists of the metrics that measure the flexibility of the company to gain a competitive advantage in the market (APICS, 2017).
Table 6: Agility Model Data

<table>
<thead>
<tr>
<th>Cluster</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industry</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agriculture</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Construction</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Education</td>
<td>1</td>
<td>4</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Financial Services</td>
<td>11</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Food Industry</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Sales</td>
<td>6</td>
<td>3</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>Sports; Football Field</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Technology</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

Figure 10: Agility Model Cluster Plot
Applying the k-Means clustering algorithm over the full dataset of 63 respondents relative to their responses on the frequency with which they measure the Agility SCOR metrics, but excluding the demographic indicators, a set of 4 clusters was obtained. It can be noted from Figure 10: Agility Model Cluster Plot that Cluster 1 contains the most financial services companies among all other clusters, and the centroid of Cluster 1 is the farthest left centroid in the diagram which means that the financial services industry measures the agility performance metrics the most among all other industries.

Figure 11: Agility Model Heat Map
In order to gain more insight into what differentiates the clusters from each other, a heat-map that contains all Agility SCOR metrics relative to the centers of each cluster is presented in Figure 11. Furthermore, Table 6: Agility Model Data relates the number of companies belonging to each industry relative to Cluster membership. As it was mentioned before, Cluster 1 appears to represent the financial services industry and the dark red color of the Cluster 1 column indicates that this cluster is dominated by companies which measure the level one and level 2 agility performance metrics more frequently than the other companies. The majority of companies in cluster 2 are from sales and education industries, and these companies measure level 2 agility performances more than Level 1 except for the probability of risk event and cost of risk event. Next, Cluster 3 which is made up of a combination of three industries: Construction, education and technology measures these two level 2 performance metrics of the maximum sustainable percentage increase in production that can be achieved in 30 days and the production reduction sustainable at 30 days prior to delivery with no inventory or cost penalties the most frequently in comparison to other agility performance metrics. Cluster 4 is dominated by sales and education. In this cluster, the companies don’t measure the agility performance metrics at all, as the dark blue color is dominated in this cluster.
Lastly, Figure 12 shows what the cluster diagram wasn’t able to show based on the seven demographic questions in the survey. The Agility Model tree diagram shows that the most important partition to derive cluster membership is industry. Specifically, the root node yields two branches, the first branch is made up of the agriculture, construction and financial industries. And the second branch that is made up of education, sales, technology and sports industries, and this branch yields two sub-branches as well. The first sub branch is for the companies which sizes vary between 0-100 and 300-400 employees -- this sub branch shows that the older companies in this sample are most likely to fall into Cluster 2, while the companies that are new in the market are more likely to fall in Cluster 1. While the companies that have number of employees varies from 100 up to 300 employees likely lay down in cluster number 3.
4.2.5 Cost Model Performance:

Cost performance measures all the costs that are associated with the supply chain management process from Cost of Goods Sold, Labor Costs, Transportation Cost to all Total Supply Chain Management costs (APICS, 2017).

Table 7: Cost Model Data

<table>
<thead>
<tr>
<th>Industry</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Construction</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Education</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>0</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Financial Services</td>
<td>11</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Food Industry</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Sales</td>
<td>2</td>
<td>0</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>6</td>
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<tr>
<td>Sports; Football Field</td>
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<td>Technology</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>

Figure 13: Cost Model Cluster
Applying the clustering algorithm over the full dataset of 63 respondents relative to their responses on the frequency with which they measure the cost metrics, but excluding the demographic indicators, a set of 6 clusters was obtained. These clusters are shown in Figure 13 which shows that all observations form six homogenous and distinct clusters for level 1 performances on dimension 1 and level 2 and 3 performances on dimension 2. The observations that are in the same cluster are similar to each other with respect to how frequently each company measures the agility performance metrics. It can be noted from Table 7 that Cluster 1 contains the most financial services companies among all other clusters, and the centroid of Cluster 1 is the farthest left centroid in the diagram which means that the financial services industry measures the cost performances the most among all other industries.

![Cost Model Heat Map](image_url)
In order to gain more insight into what differentiates the clusters from each other, a heat-map that contains all cost-related SCOR metrics relative to the centers of each cluster is presented in Figure 14. Furthermore, Table 7 relates the number of companies belonging to each industry relative to Cluster membership. As was mentioned before, Cluster 1 appears to represent the financial services industry, and the Cluster 1 column indicates that companies in this cluster dominated by financial services companies that measure level 1, 2, and level 3 of cost performance metrics more frequently than the other companies. Cluster 2 is made up of education companies and thus this cluster measures the cost performance metrics the least between all the other clusters, and it can be noticed that they don't measure the cost to deliver and direct labor cost at all in this cluster. Cluster 3 contains both education and sales industries, these companies measure the cost performance metrics least frequently than the other clusters except for the cost of goods sold metric which these companies measure it on an average basis. Cluster 4 is made up of the sales industry only and these companies measure level 2 and level 3 cost performance metrics on average, while they measure level 1 cost performance metrics on a frequent basis. Cluster 5 is a combination of education and technology sectors and these companies measure all the cost performance metrics on average except for the measurement of cost of goods sold which they measure it less frequently than the average. Moreover, Cluster 6 is made up of sales, construction, and education industries and these companies seem to measure Level 2 and 3 of cost performance metrics more frequently than level 1.
Lastly, Figure 15, the Tree-Diagram E shows what the cluster diagram wasn’t able to show based on the seven demographic questions in the survey. This tree was derived from the data using the evtree package in R (Grubinger et al., 2014). The tree diagram shows that the most important partition to derive cluster membership is an industry. Specifically, the root node yields two branches, the first branch is made up of the agriculture, education, financial services, and sports industries which also has two sub-branches, the first sub-branch shows that these companies predominantly fall in Cluster 1 while the second sub-branch differentiates the companies by the size. Companies with up to 200 employees generally fall in Cluster 2 while they fall in Cluster 5 if containing up to 400 employees. Furthermore, the second branch consists of companies that belong to the construction, sales, and goods industries. If the number of employees in these companies is between 100 and 300. The companies belong to Cluster 5. While the companies that have employees on the order of 300 and above fall in Cluster 4.

4.2.6 Asset Management Model Performance:

The asset management performance measures the ability to utilize assets as it is

Figure 15: Cost Model Tree Diagram
directly related to supporting the demand satisfaction of the company, the asset management metrics are divided into three categories that are the Cash-to-Cash cycle Time, Inventory days of supply, and Asset Turns (APICS, 2017).

Table 8: Asset Management Table

<table>
<thead>
<tr>
<th>Industry</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Construction</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Education</td>
<td>3</td>
<td>0</td>
<td>5</td>
<td>1</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Financial Services</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>11</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Food Industry</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Sales</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Sports; Football</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Technology</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

Figure 16: Asset Management Model Cluster
Applying the k-Means clustering algorithm over the full dataset of 63 respondents relative to their responses on the frequency with which they measure the asset management metrics, but excluding the demographic indicators, a set of 6 clusters was obtained. These clusters are shown in Figure 16: Asset Management Model Cluster. This shows that all observations form six homogenous and distinct clusters concerning the Asset Management Metrics. The observations that are in the same cluster are similar to each other for how frequently each company measures the agility performance metrics. It can be noted in Figure X that Cluster 4 has the most financial services companies among all other clusters, and the centroid of Cluster 4 is the farthest left centroid in the diagram which means that the financial services industry measures the cost performances the most among all other industries.

![Figure 17: Asset Management Model Heat Map](image)
In order to gain more insight into what differentiates the clusters from each other, a heat-map that contains all asset management metric performances relative to the centers of each cluster is presented in Figure F. Furthermore, Table 7 relates the number of companies belonging to each industry relative to Cluster membership. First of all, Cluster 1 is made up of a combination of education and sales companies, and the heat map has shown that these companies measure level 2 asset management performances more than level 1 asset management metrics. Cluster 2 which contains an equal number of companies for construction, sales, and technology industries is the opposite of Cluster 1, as these companies measure level 1 asset management performance a lot more frequently than level 2 performances. Cluster 3 represents the education and sales companies do not measure these performances at all except for return on fixed assets and return on working capital they measure those metrics a little bit more than the other performance --once a month for example.

Cluster 4 appears to represents the financial services industry and the dark red color of the Cluster 4 column indicates that companies in this cluster, dominated by financial services companies, measure the Level 1 and Level 2 asset management metrics more frequently than the others. The majority of companies in Cluster 5 belong to the sales industry and these companies measure return on fixed assets and return on working capital more frequently than the other metrics as opposite to Cluster 3. Cluster 6 which is made up of the education industry measures all the asset management performance at the average frequency and nothing more.
Lastly, Figure 18, the asset management model tree diagram shows what the cluster diagram wasn't able to show based on the seven demographic questions in the survey. This tree was derived from the data using the evtree package in R (Grubinger et al., 2014). The tree diagram shows that the most important partition to derive cluster membership is an industry. Specifically, the root node yields two branches, and there is something special in this tree diagram is that the first main two branches are differentiated by the age of the company and not by the industry as the previous ones. The first branch contains the companies that have been functioning up to 50 years, and if the company applies the SCOR model they generally fall in cluster 4, and if not they fall in cluster 2. The second main branch in this tree is made up of the companies that are among the oldest in the sample, and these companies are divided into two sub-branches according to the industry they belong in. The first sub-branch shows that construction and financial services belong to Cluster 1. The majority of the food industry and sales companies belong to Cluster 6 and sales and sports belong to Cluster 4.
Chapter Five

Conclusion

A successful supply chain management system is the first term to think about in order to achieve a competitive advantage in the market. The SCOR model presents common metrics that make it easier for the company to know where it stands, and how to grow in the market. This study addresses a set of SCOR model performance metrics to understand how companies within the MENA region are implementing supply chain management measurement systems such as SCOR. From the analysis presented in this study, it can be noticed that there is a cluster of companies dominated by the financial sector for which measuring all SCOR Metrics more frequently than the average is important. In contrast there is another cluster, dominated by the education sector, for which measuring all SCOR Metrics less frequently that the average is the norm. It can be seen in the gray area between the two extremes that there is a cluster measuring Level 1 metrics more frequently than the Level 2 metrics of which the Level 1 metric is comprised. There is also a cluster comprised of companies that measure the Level 1 metric frequently but claim not to be tracking the Level 2 metrics.

From the 1990s, the Lebanese economy has been standing in the banking sector. It can be concluded from this study that the Financial Sector in Lebanon is doing their job right. As Figure 3 shows these financial companies measure all SCOR model metrics above average without any exception and tracking all of these SCOR metrics made the banking sector in Lebanon the biggest among all other sectors.

In contrast, the education sector is well behind in its application of supply chain monitoring. This cluster doesn’t measure any metric frequently, and this may be one
reason why some of the schools have been declaring their bankruptcy in Lebanon, especially during the recent economic crises. The Education sector, and schools, in particular, must work on measuring the cost and asset management processes the most, the same as the financial sector because their profitability depends on the revenues they generate from the tuitions and expenses they pay to the staff as direct and indirect labor costs. Also, most of the schools provide uniforms and/or sell books, so it is reasonable to expect that the schools use Reliability and Responsiveness, Agility metrics too.

The sales sector measures the agility performance metric the most because this area focuses on holding goods as a means to buffer against instability. Especially in Lebanon, the sales sector cares about being flexible and able to react directly to the market changes more than any other metric. This sector seeks to hold just the right amount of inventory and push that inventory to the market. What doesn’t make sense relative to this sector is the low frequency with which they measure the Cost and Asset Management performances because the sales sector should also care for the financial performance.

To elaborate more, Cluster 1 – made up predominantly of sales companies -- in the reliability model pays attention to the total number of orders the most, as these companies measure this metric more frequently than the total number of perfect orders. These companies ignore the importance of Level 1 reliability performance as they measure it below average, although it is the Level 1 performances that would bring these companies closer to the supply chain management processes. Opposing Cluster 1 is Cluster 2 that is made up of education and the older sales companies, this cluster measures Level 1 reliability performance more than Level 2, as they look at supply chain management as one big picture. Cluster 3 is made up of the financial...
services industries, and this industry measures Level 1 and Level 2 of reliability performance metrics more frequently than the other industries. In contrast to Cluster 4, which is dominated by the education industry who only minimally measures reliability performances. No matter how old is the company in Cluster 4, they still do not rely on reliability performance. In contrast, in Cluster 5, the age of the company plays an important role in distinguishing sales and technology companies, it can be noticed that the older the company in the market, the more they measure the reliability performance metrics. As the new companies in the markets likely do not know the importance of or how to measure reliability to attain a competitive advantage.

The most interesting metric in the Responsiveness area is the make cycle time, it can be noted that every cluster measures it differently. The Education industry in Cluster 1 does not measure it at all, while the financial services companies in Cluster 2 measure it frequently. Although Cluster 3 and Cluster 4 are made up of sales and education industries, Cluster 3 measures the order fulfillment cycle time and make cycle time less frequently than the other metrics, in contrast to Cluster 4.

Cluster 1 in the agility performance area is made up of the financial services and as is consistent with all other areas, they measure both Level 1 and Level 2 metrics with great frequency. This is dissimilar to Cluster 4 (dominated by Education) that do not measure these metrics at all. Furthermore, Cluster 2 is made up of education and the older sales companies do not measure Level 1 metrics but measure Level 2 agility performance metrics except for the risk measurements such as cost of a risk event and the time to recover. The surprise in agility performance metric measurement lays in Cluster 3 that is up of the construction industry, it is usually known that the construction companies always have products on hold in case of deficiency, but the
story here tells the opposite. Cluster 3 measures the Level 1 metrics and the risk measurement of Level 2 most frequently, but not the materials agility metrics. In other words, this cluster cares about risk (likely bodily harm to workers on-site or structural deficiencies in the building), but not the measurement of those material actions that would buffer against financial risk.

This study showed that the majority of the Lebanese companies did not hear about the SCOR model before. From the beginning of October, when the Lebanese revolution started, most of the shelves at the supermarket were found empty, this may be due to the absence of measuring the reliability, responsiveness, and agility metrics suggested in the SCOR system. Besides, we see a high number of stores and institutions that closed during the latest Lebanese financial crises which may indicate that they didn’t measure the cost and the asset management performance metrics on a frequent basis. In can be concluded that any institution, regardless of the sector to which it belongs, must adopt the SCOR model, despite the huge cost that it takes to implement the strategy, but once the company implements it correctly, the profits would be significantly higher.

It can be shown from Figure 3 that applying the SCOR metrics performance differ from one industry to another, as measuring the SCOR model is highly prevalent in financial industries and is absent in the education sector. It can be concluded that the term SCOR is still not clear within the Lebanese industries, as it is impossible for the education industry, such as schools and universities, not to measure the costs of the expenses and assets they have.

This study showed the importance of supply chain management, and one of the most important parts of the supply chain management is the teamwork and the cooperation between the managers and the employees inside service companies rather
than traditional assembly lines. It would be recommended that the managers inside all the companies introduce the SCOR supply chain management tool and discuss how important it is to implement a successful SCOR model tool. And based on the results and the differences between the industries, it would be highly recommended to design a SCOR model specific to every industry. For example, for a SCOR model in the education sector we would remove some of the responsiveness model metrics as Make Cycle Time and Source cycle time and add some cost metrics in a more detailed way for example Cost of Books and Costs related to funding. Moreover, for future work, it would be more interesting if we do a future research on measuring the success of older sales companies in the market based on the frequency with which they measure the SCOR performance model elements.

During this past year of revolutions and pandemics, multiple challenges were faced and imposed limitations on this work. Specifically, we were unable to reach the desired number of respondents, nor could the results be supplemented with interviews with some managers to discuss the supply chain management tools that they use in their companies. This research paper recommends extending this study to develop a SCOR model flexible enough to suits all Lebanese sectors – and predominately the service sectors -- at a minimal cost.
Bibliography


Desa, U. (Director). (2017). he UN Least Developed Country category [Motion Picture].


Appendices

Appendix A

Appendix A includes the survey in full:

1. Have you heard of the Supply Chain Operations Reference (SCOR) model?
   - Yes
   - No

2. Does your company use the Supply Chain Operations Reference (SCOR) model?
   - Yes
   - No

3. Does your company provide training in the Supply Chain Operations Reference (SCOR) model?
   - Yes
   - No

4. What is the average age of the employees (Years)
   - 20-30
   - 30-40
   - 40-50
   - 50-60
   - 65+

5. What is the age of the company/how long has your company been in operation?
• 0-5 Years
• 5-10 Years
• 10-15 Years
• 15-20 Years
• 20+ Years

6. What is the company’s industry?

• Sales
• Technology
• Education
• Construction
• Financial services

7. What is the size of your company

• 0-100
• 100-200
• 200-300
• 300-400
• 400+
1. How often does your company measure?

<table>
<thead>
<tr>
<th></th>
<th>Never</th>
<th>Once per Year (Annually)</th>
<th>Twice Per Year (Semi-Annually)</th>
<th>Four times per Year (Quarterly)</th>
<th>Monthly</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Perfect Order Fulfillment</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Order Fulfillment Cycle Time</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Upside Supply Chain Adaptability</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>4</td>
<td>Downside Supply Chain Adaptability</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Overall Value-at-Risk (VaR)</td>
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<tr>
<td>6</td>
<td>Total SC Management Cost</td>
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<td>Cost of Goods Sold (COGS)</td>
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<td>Cash to Cash Cycle Time</td>
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<td>Return on Fixed Assets</td>
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<td></td>
</tr>
<tr>
<td>10</td>
<td>Return on Working Capital</td>
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2. How often does your company measure?

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<th>Four times per Year (Quarterly)</th>
<th>Monthly</th>
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<td>Total Numbers of Orders</td>
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<td>3</td>
<td>Source Cycle Time</td>
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<td></td>
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<td>4</td>
<td>Make Cycle Time</td>
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</tr>
<tr>
<td>5</td>
<td>Deliver Cycle Time</td>
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<tr>
<td>7</td>
<td>Delivery Retail Cycle Time</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Return Cycle Time</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Maximum sustainable percentage increase in raw material quantities that can be acquired/received in 30 days</td>
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<td>Maximum sustainable percentage increase in production that can be</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Maximum sustainable percentage increase in quantities delivered that can be achieved in 30 days</td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>-----</td>
<td>-----------------------------------------------------------------------------------------------</td>
<td></td>
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<td>11</td>
<td>Maximum sustainable percentage increase in returns of raw materials to suppliers that can be achieved in 30 days</td>
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<td>12</td>
<td>Maximum sustainable percentage increase in returns of finished goods from customers that can be achieved in 30 days</td>
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<td>13</td>
<td>Raw material quantity reduction sustainable at 30 days prior to delivery with no inventory or</td>
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<td>Product reduction sustainable at 30 days prior to delivery with no inventory or cost penalties</td>
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<td>Reduction in delivered quantities sustainable at 30 days prior to delivery with no inventory or cost penalties</td>
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<td>Inventory Days of Supply</td>
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<td>Days Payable Outstanding</td>
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<td>Supply Chain Fixed Assets</td>
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<td>Accounts Payable</td>
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<td>Accounts Receivable</td>
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<td>Inventory</td>
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</table>
Appendix B

Appendix B includes the full R-Script used to analyze the full data on R Studio:

1. data<‐read.csv("RawData_02042020.csv")
2. #Load needed packages
3. library(tidyverse) # data manipulation
4. library(cluster) # clustering algorithms
5. library(factoextra) # clustering algorithms & visualization
6. library(psych) #Statistics commands
7. library(dplyr) #For data manipulation commands
8. library(RColorBrewer) #For color scale in charts
9. library(evtree) # for decision trees
10. # Create a color palette to be used for heatmaps
11. hm.palette <-colorRampPalette(rev(brewer.pal(10, 'RdYlBu')),space='Lab')
12. #Setup collection of Level 1 items for easier reference
13. Level2<‐
c("RL.2.1","RL.2.2","RS.2.1","RS.2.2","RS.2.3","RS.2.4","RS.2.5","AG.2.1 ","AG.2.2","AG.2.3","AG.2.4","AG.2.5","AG.2.6","AG.2.7","AG.2.8","AG. 2.9","AG.2.11","AG.2.12","CO.2.1","CO.2.2","CO.2.3","CO.2.4","CO.2.5"," CO.2.6","CO.3.1","CO.3.2","CO.3.3","AM.2.1","AM.2.2","AM.2.3","AM. 2.4","AM.2.5","AM.2.6","AM.2.7","AM.2.8")#Setup collection of Level 2 items for easier reference
14. Level2<‐c("RL.2.1","RL.2.2","RS.2.1","RS.2.2","RS.2.3","RS.2.4","RS. 2.5","AG.2.1","AG.2.2","AG.2.3","AG.2.4","AG.2.5","AG.2.6","AG.2.7"," AG.
15. 2.8","AG.2.9","AG.2.11","AG.2.12","CO.2.1","CO.2.2","CO.2.3","CO.2.4"," CO.
16. 2.5","CO.2.6","CO.3.1","CO.3.2","CO.3.3","AM.2.1","AM.2.2","AM.2.3"," AM.
17. 2.4","AM.2.5","AM.2.6","AM.2.7","AM.2.8")
18. #Setup SCOR Performance Metric Categories
19. RL_L1<‐c("RL.1")
20. RL_L2<‐c("RL.2.1","RL.2.2")
21. RS_L1<‐c("RS.1")
22. RS_L2<‐c("RS.2.1","RS.2.2","RS.2.3","RS.2.4","RS.2.5")
23. AG_L1<‐c("AG.1.1","AG.1.2","AG.1.3")
24. AG_L2<‐c("AG.2.1","AG.2.2","AG.2.3","AG.2.4","AG.2.5","AG.2.6","AG.
25. 2.7","AG.2.8","AG.2.9","AG.2.11","AG.2.12")
26. CO_L1<‐c("CO.1.1","CO.1.2")
27. CO_L2<‐c("CO.2.1","CO.2.2","CO.2.3","CO.2.4","CO.2.5","CO.2.6")
29. CO_L3 <- c("CO.3.1", "CO.3.2", "CO.3.3")
30. AM_L1 <- c("AM.1.1", "AM.1.2", "AM.1.3")
31. AM_L2 <- c("AM.2.1", "AM.2.2", "AM.2.3", "AM.2.4", "AM.2.5", "AM.2.6", "AM.2.7", "AM.2.8")
32. ResilienceMetrics <- c(AG_L1, AG_L2, RL_L1, RL_L2, RS_L1, RS_L2)
33. FinancialMetrics <- c(AM_L1, AM_L2, CO_L1, CO_L2, CO_L3)
34. AssetManagementMetrics <- c(AM_L1, AM_L2)
35. ReliabilityMetrics <- c(RL_L1, RL_L2)
36. ResponsivnessMetrics <- c(RS_L1, RS_L2)
37. CostMetrics <- c(CO_L1, CO_L2, CO_L3)
38. AllModel <- c(Level1, Level2)
39. # Setup dataset with only metric data
40. metricData <- data[, AllModel]
41. # Make sure that the factor values are set in the right order from Never to Monthly
42. metricData <- data.frame(lapply(metricData, function(x) as.numeric(factor(x, levels = c("Never", "Once Per Year (Annually)", "Twice Per Year (Semi-Annually)", "Four Times Per Year (Quarterly)", "Monthly")))))
43. # Build Summary for values of all variables
44. describe(metricData)
45. # Add row names for the industry to the metricData
46. rownames(metricData) <- paste0(data$Q6, c(1:nrow(data)))
47. # Scale the data for use in Cluster Analysis
48. metricData_Scaled <- scale(metricData)
49. # Method to study the distances between each row in the data; here we are using Euclidean distance
50. distance <- get_dist(metricData_Scaled)
51. # Visualize the distance between each record in the data; the blue squares indicate a close distance, the orange indicates a larger distance (e.g., more dissimilarity in records)
52. fviz_dist(distance, gradient = list(low = "#00AFBB", mid = "white", high = "#FC4E07"))
53. # Result: This picture should be included in the thesis -- it shows that generally financial services and education are "far" apart in terms of their metric measurement frequency.
54. # To ensure replicability of clustering when made with random starts
55. set.seed(123)
56. # Build a Cluster analysis on all the scaled data specifying 5 centers
68. AllDataCluster <- kmeans(metricData_Scaled, centers = 5, nstart = 25)
69. #Build a visualization of the clusters
70. fviz_cluster(AllDataCluster, data = metricData, repel=TRUE)
71. #ADD CLUSTER VARIABLE TO metric Data
72. data$fullModel_Cluster<-AllDataCluster$cluster
73. #create table of clusters vs industry
74. table(data$Q6,data$fullModel_Cluster)
75. #CODE TO VISUALIZE DIFFERENCE ACROSS CLUSTERS
    RELATIVE TO VARIABLES
76. center <-AllDataCluster$centers
77. # create dataset with the cluster number
78. cluster <- c(1:5)
79. center_df <- data.frame(cluster, center)
80. # Reshape the data to present the scales for every metric in the model
81. center_reshape <- gather(center_df, features, values, AllModel)
82. ggplot(data = center_reshape, aes(x = cluster, y = features, fill =
    values)) +
83. geom_tile() +
84. coord_equal() +
85. scale_fill_gradientn(colours = hm.palette(90))
86. #Decision tree to map demographics to clusters in overall model
87. fullModel_tree<-evtree(as.factor(fullModel_Cluster) ~ Q1 + Q2 + Q3 + Q4
    +Q5 + Q6 + Q7 +Q8, data)
88. plot(fullModel_tree)
89. #NOTE: This figure should be included in the thesis -- in caption note that
90. values are scaled such that 0 is the mean level of that metric; 1 indicates
91. a higher frequency of measurement and -1 indicates a lower frequenc of
92. measure
93. #### BUILD NEW MODELS FOR EACH SCOR AREA
94. #AGILITY MODEL -- 4 clusters
95. cluster<-c(1:4)
96. AgilityModel <- kmeans(metricData_Scaled[,c(AG_L1,AG_L2)], centers =
    4,
97. nstart = 25)
98. #Add agility cluster variable to the data
99. data$agilityCluster<-AgilityModel$cluster
100. #create table of clusters vs industry
101. table(data$Q6,data$agilityCluster)
102. #Visualize Agility Clusters
viz_cluster(object = AgilityModel, data = metricData[,c(AG_L1,AG_L2)], repel=TRUE)

# Visualize metrics relative to clusters
center <- AgilityModel$centers
center_df <- data.frame(cluster, center)

# Reshape the data
center_reshape <- gather(center_df, features, values, c(AG_L1,AG_L2))
center_reshape$features <- as.factor(center_reshape$features)
center_reshape$features<-factor(center_reshape$features, levels = c(AG_L1,AG_L2))
ggplot(data = center_reshape, aes(y = features, x = cluster, fill = values)) +
  scale_x_continuous(breaks = seq(1, 7, by = 1)) +
  geom_tile() +
  coord_equal() +
  scale_fill_gradientn(colours = hm.palette(90))

# Decision tree demographics predicting cluster
ag_tree<-evtree(as.factor(assetMgtCluster) ~ Q1 + Q2 + Q3 + Q4 + Q5 + Q6 + Q7 +Q8, data)
plot(ag_tree)

# ASSET MANAGEMENT MODEL
# 6 clusters
cluster<-c(1:6)
AssetMgtModel <- kmeans(metricData_Scaled[,c(AM_L1,AM_L2)], centers = 6,
nstart = 25)

# Add AM cluster variable to the data
data$assetMgtCluster<- AssetMgtModel$cluster

# Create table of clusters vs industry
table(data$Q6, data$assetMgtCluster)

# Visualize AM Clusters
viz_cluster(object = AssetMgtModel, data = metricData[,c(AM_L1,AM_L2)], repel=TRUE)

# Visualize metrics relative to clusters
center <- AssetMgtModel$centers
center_df <- data.frame(cluster, center)

# Reshape the data
center_reshape <- gather(center_df, features, values,
c(AM_L1, AM_L2))

142. ggplot(data = center_reshape, aes(y = features, x = cluster, fill =
143. values)) +
144. scale_x_continuous(breaks = seq(1, 7, by = 1)) +
145. geom_tile() +
146. coord_equal() +
147. scale_fill_gradientn(colours = hm.palette(90))
148. # decision tree demographics predicting cluster
149. am_tree <- evtree(as.factor(assetMgtCluster) ~ Q1 + Q2 + Q3 + Q4 +
150. Q5 + Q6 + Q7 + Q8, data)
151. plot(am_tree)
152. # COST MODEL
153. # 6 centers for clusters
154. cluster <- c(1:6)
155. CostModel <-
156. kmeans(metricData_Scaled[, c(CO_L1, CO_L2, CO_L3)], centers = 6,
157. nstart = 25)
158. # Add cost cluster variable to the data
159. data$costCluster <- CostModel$cluster
160. # create table of clusters vs industry
161. table(data$Q6, data$costCluster)
162. # Visualize cost Clusters
163. fviz_cluster(object = CostModel, data =
164. metricData[, c(CO_L1, CO_L2, CO_L3)], repel = TRUE)
165. # Visualize metrics relative to clusters
166. center <- CostModel$centers
167. center_df <- data.frame(cluster, center)
168. # Reshape the data
169. center_reshape <- gather(center_df, features, values,
170. c(CO_L1, CO_L2, CO_L3))
171. ggplot(data = center_reshape, aes(y = features, x = cluster, fill =
172. values)) +
173. scale_x_continuous(breaks = seq(1, 7, by = 1)) +
174. geom_tile() +
175. coord_equal() +
176. scale_fill_gradientn(colours = hm.palette(90))
177. # decision tree demographics predicting cluster
178. co_tree <- evtree(as.factor(costCluster) ~ Q1 + Q2 + Q3 + Q4 + Q5 +
179. Q6 + Q7 + Q8, data)
180. plot(co_tree)
co_tree

#Reliability MODEL

#Use 5 clusters

cluster<-c(1:5)

RLModel <- kmeans(metricData_Scaled[,c(RL_L1,RL_L2)], centers = 5, nstart = 25)

#Add cost cluster variable to the data

data$relCluster<-RLModel$cluster

#create table of clusters vs industry

table(data$Q6,data$relCluster)

#Visualize cost Clusters

tviz_cluster(object = RLModel,data = metricData[,c(RL_L1,RL_L2)],
repel=TRUE)

#Visualize metrics relative to clusters

center <-RLModel$centers

center_df <- data.frame(cluster, center)

# Reshape the data

center_reshape <- gather(center_df, features, values,
c(RL_L1,RL_L2))

ggplot(data = center_reshape, aes(y = features, x = cluster, fill = values)) +
scale_x_continuous(breaks = seq(1, 7, by = 1)) +
geom_tile() +
coord_equal() +
scale_fill_gradientn(colours = hm.palette(90))

#decision tree demographics predicting cluster

rl_tree<-evtree(as.factor(relCluster) ~ Q1 + Q2 + Q3 + Q4 + Q5 + Q6 + Q7+Q8, data)

plot(rl_tree)

classify = predict(rl_tree)

table(data$Q6, classify)

#Responsiveness MODEL

# 4 clusters

cluster<-c(1:4)

RSModel <- kmeans(metricData_Scaled[,c(RS_L1,RS_L2)], centers = 4, nstart = 25)

#Add cost cluster variable to the data

data$resCluster<-RSModel$cluster

#create table of clusters vs industry

table(data$Q6,data$resCluster)
# Visualize cost Clusters
fviz_cluster(object = RSModel, data = metricData[,c(RS_L1,RS_L2)], repel=TRUE)

# Visualize metrics relative to clusters
center <- RSModel$centers
center_df <- data.frame(cluster, center)
# Reshape the data
center_reshape <- gather(center_df, features, values, c(RS_L1,RS_L2))
ggplot(data = center_reshape, aes(y = features, x = cluster, fill = values)) +
  scale_x_continuous(breaks = seq(1, 7, by = 1)) +
  geom_tile() +
  coord_equal() +
  scale_fill_gradientn(colours = hm.palette(90))

# decision tree demographics predicting cluster
rs_tree <- evtree(as.factor(resCluster) ~ Q1 + Q2 + Q3 + Q4 + Q5 + Q6 + Q7 + Q8, data)
plot(rs_tree)
rs_tree
citation("cluster")
citation("evtree")